Characterization of a Prototype Wideband Airport Pseudolite, Multipath Limiting Antenna (WBAPL MLA) for the Local Area Augmentation System (LAAS)

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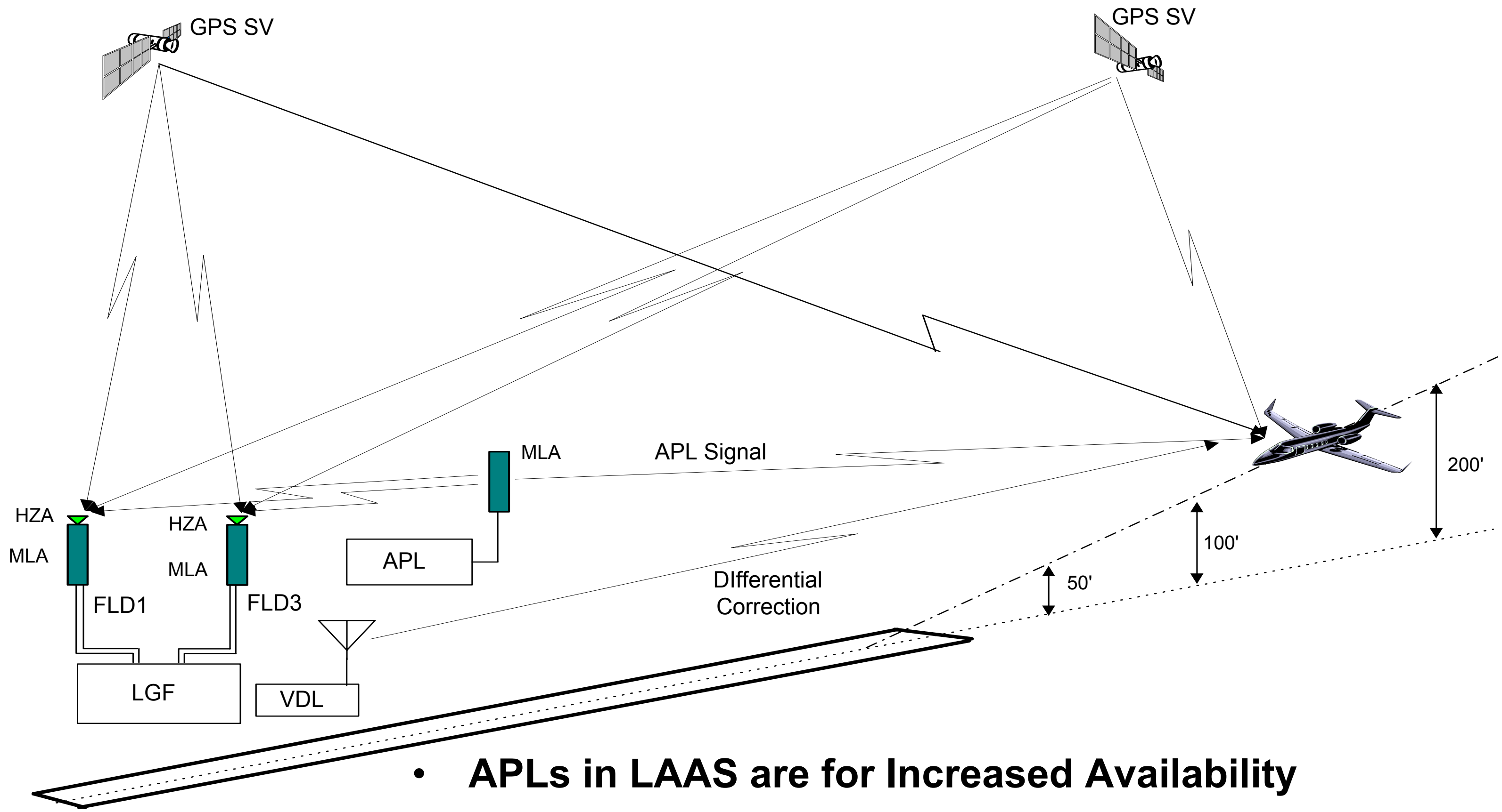
Background

- The Local Area Augmentation System (LAAS) is an augmentation to GPS which has been designed to support navigation within the airport area (approximately a 20-30 mile radius).
- Additional Ground Based Ranging Sources (such as pseudo satellites a.k.a. pseudolites) are Used to Augment the GPS Constellation Component of the LAAS in Order to Improve Availability.
- This Presentation will Focus on a New Antenna to be Used as a Transmission Antenna for Wideband Airport Pseudolite (WBAPL) Signals.

WBAPL MLA

LAAS Overview with WBAPL



- **APLs in LAAS are for Increased Availability**
- **Wideband-Only Signal is Used for Robust Performance**
- **APL(s) Modular to LAAS Design for CAT II/III**
- **Pulsing of APL Used to Maximize Interoperability with GPS**

Presentation Outline

- **LAAS Background**
- **WBAPL Introduction**
- **Description of Antenna Pattern Requirements for WBAPL Transmission**
- **Full Antenna Radiation Patterns**
- **Measured Performance Data Collected in the Field**
- **Comparison of Other Existing Technologies to Show Additional Performance Attained with a WBAPL MLA.**

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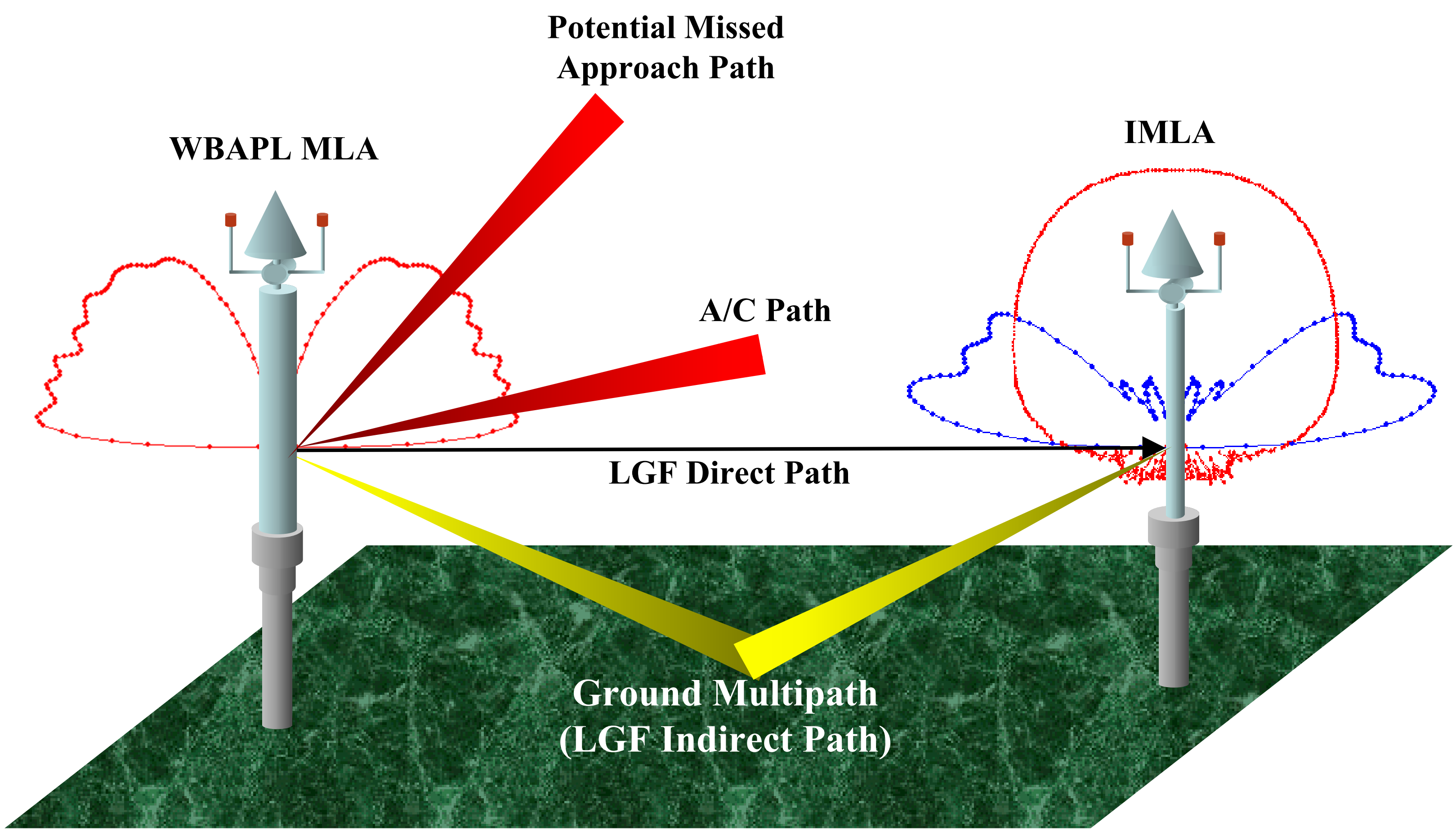
WBAPL Introduction

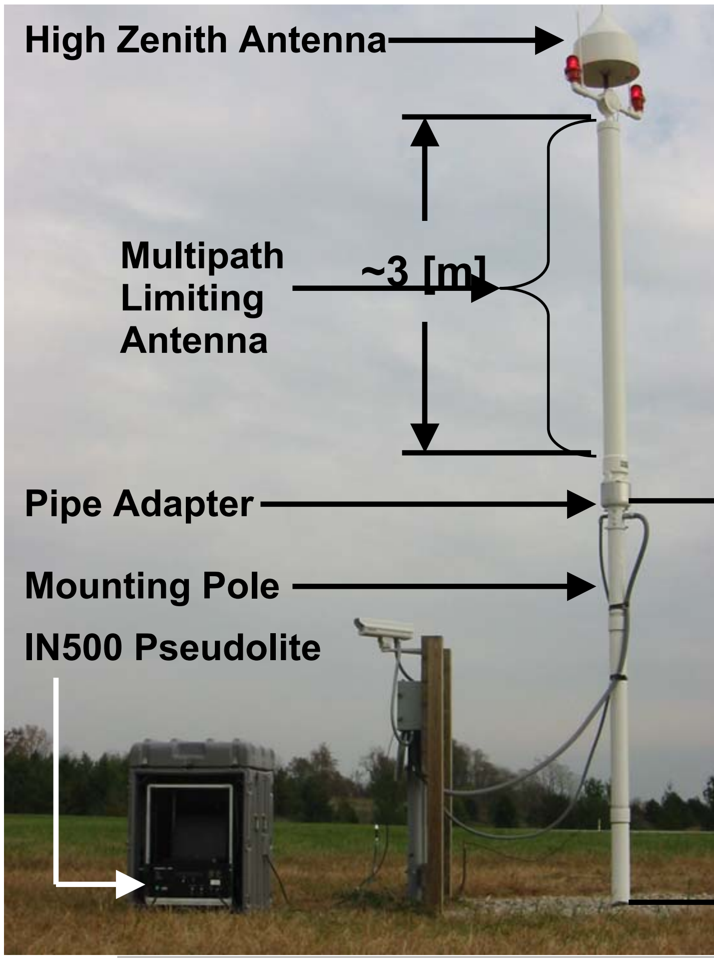
- WBAPL signals have been used as an additional ground based ranging source to augment the GPS constellation in the LAAS for over 10 years.
  - » Provide Increased Availability
  - » Provide Increased LAAS Accuracy for Reduced SV Cases
- Transmission of WBAPL signals entreats the use of a customized antenna since the required performance is different from that of GPS reception.
- A larger aperture (provided by a 20-element antenna) was selected to provide sharp rolloff about the horizon and an extended coverage volume while maintaining a high desired to undesired (D/U) ratio.

Why MLA for WBAPL Transmission?

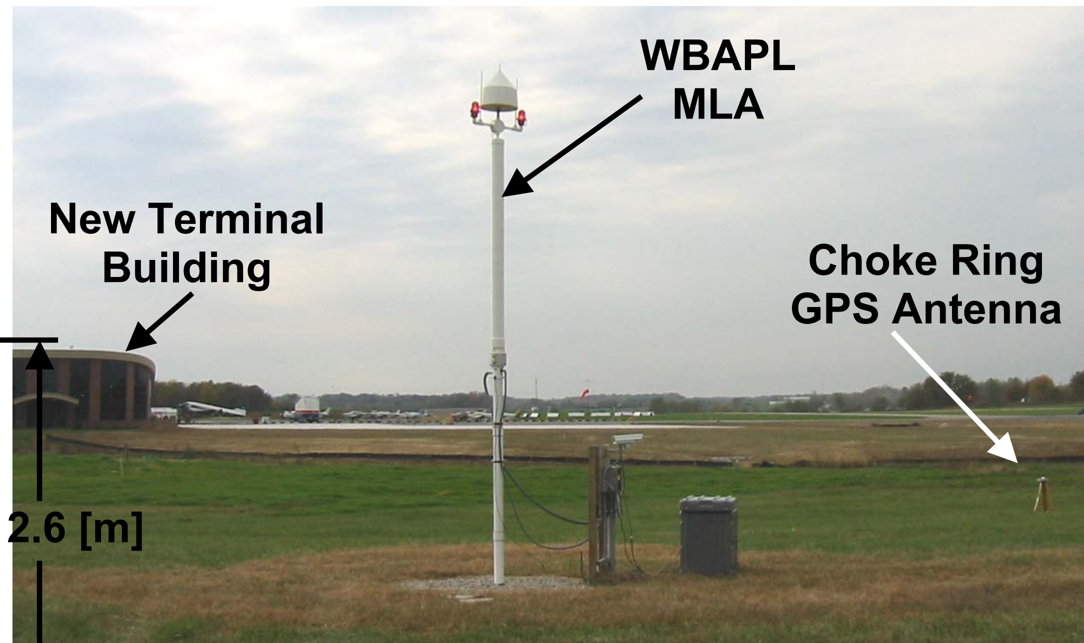


WBAPL MLA Photos

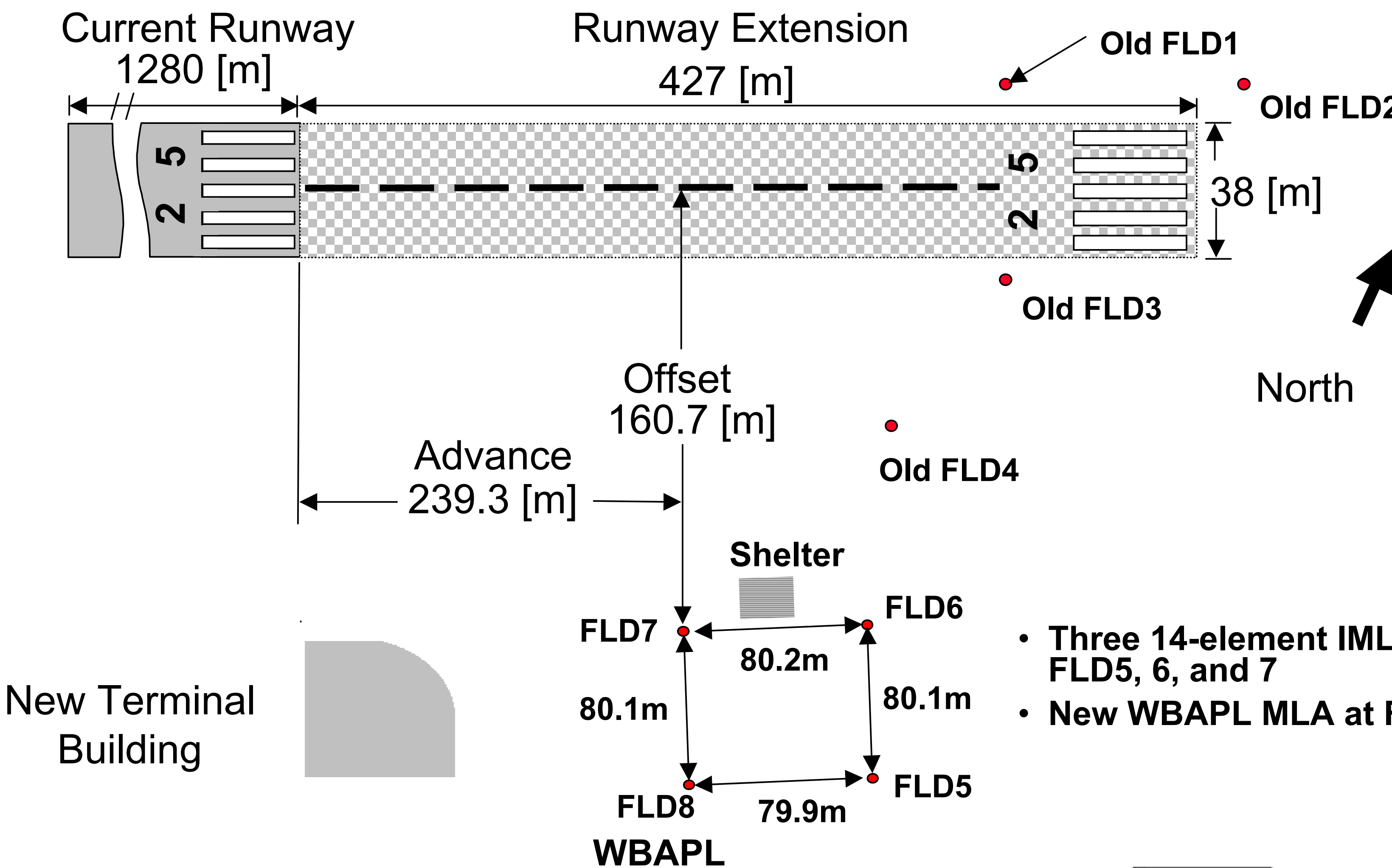
LAAS Ground Facility FLD8 Location



WBAPL MLA Shown With Respect to Airport Facilities



New Ohio University Airport (UNI) Prototype LAAS Site

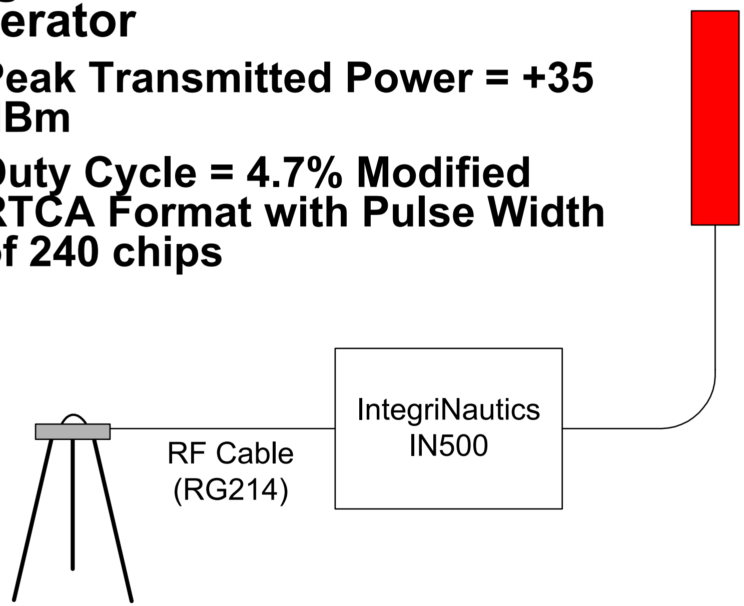


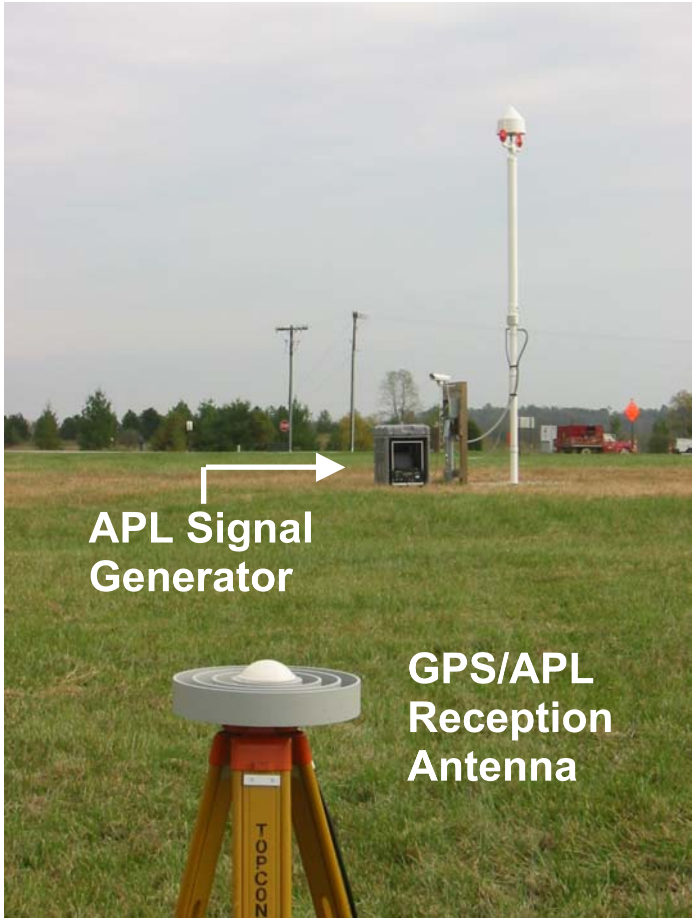
- **Three 14-element IMLAs at FLD5, 6, and 7**
- **New WBAPL MLA at FLD8**

Note: Not Shown to Scale

New WBAPL Transmission Site

- **APL Transmission via the WBAPL MLA at FLD8 (HZA not used).**
  - » **Uses a 20-element MLA Tailored for WBAPL Transmission**
- **IntegriNautics IN500 Pseudolite Generator**
  - » **Peak Transmitted Power = +35 dBm**
  - » **Duty Cycle = 4.7% Modified RTCA Format with Pulse Width of 240 chips**





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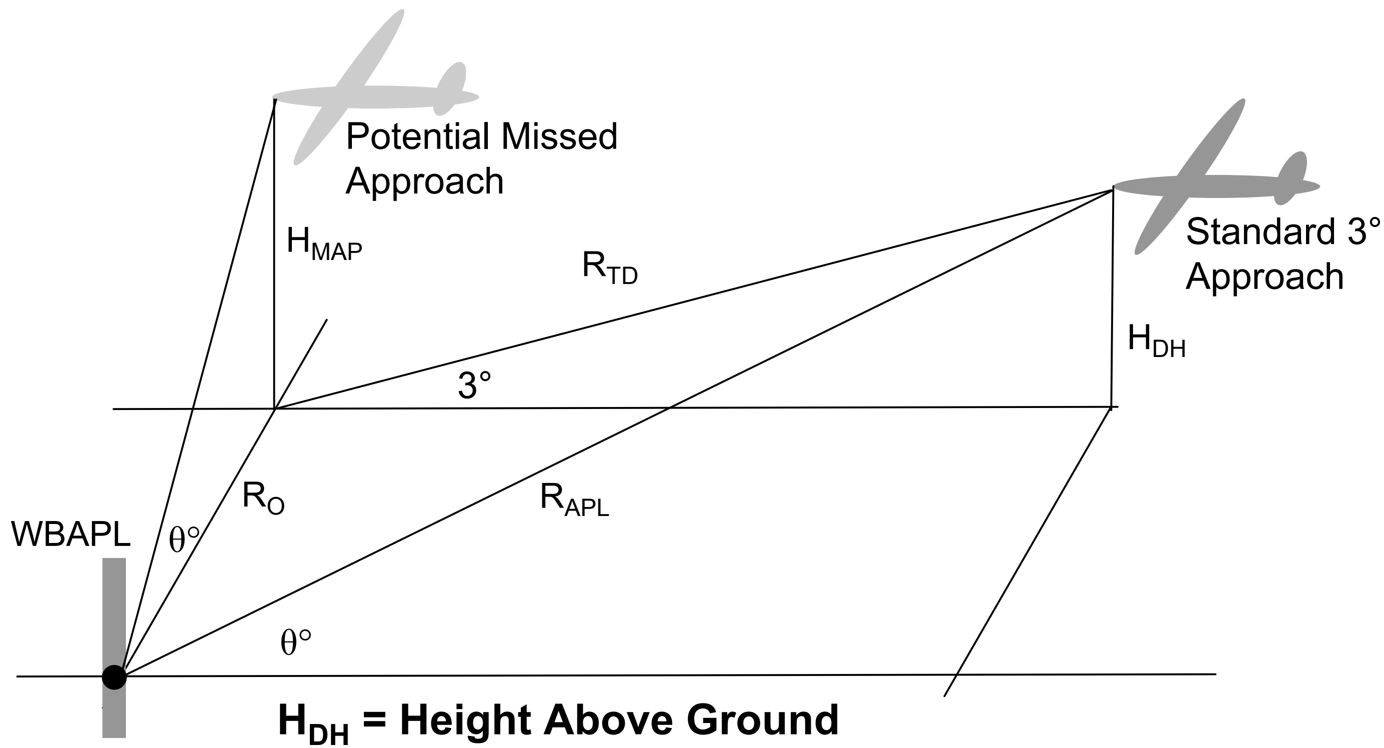
WBAPL Approach Geometry



H_{DH} = Height Above Ground
H_{MAP} = Height at Missed Approach Point
R_x = Range Terms

- **O = Offset**
- **APL = Slant Range to APL**
- **TD = Slant Range to Touchdown**

θ = Antenna Elevation Angle

Pattern Regions Defined

Elevation Angle	Primary Objective	Secondary Considerations
-3° to 0°	LGF – Multipath Rejection	APL Range – Gain (above the horizon)
-1° to 1°	LGF – Gain	Other Multipath Rejection
1° to 5°	A/C on Final - Gain	A/C on Final – Multipath Rejection
-5° to -1°	A/C on Final - Multipath Rejection	Sufficient Gain Above the Horizon
5° to 35°	APL Airport Coverage - Gain	No Performance Reduction Elsewhere
35° to 60°	GPS/APL Airport & en route Coverage – Gain	No Performance Reduction Elsewhere
60° to 90°	Overflight Coverage – Gain	No Performance Reduction Elsewhere

LGF = LAAS Ground Facility **A/C = Aircraft** **APL = Airport Pseudolite**

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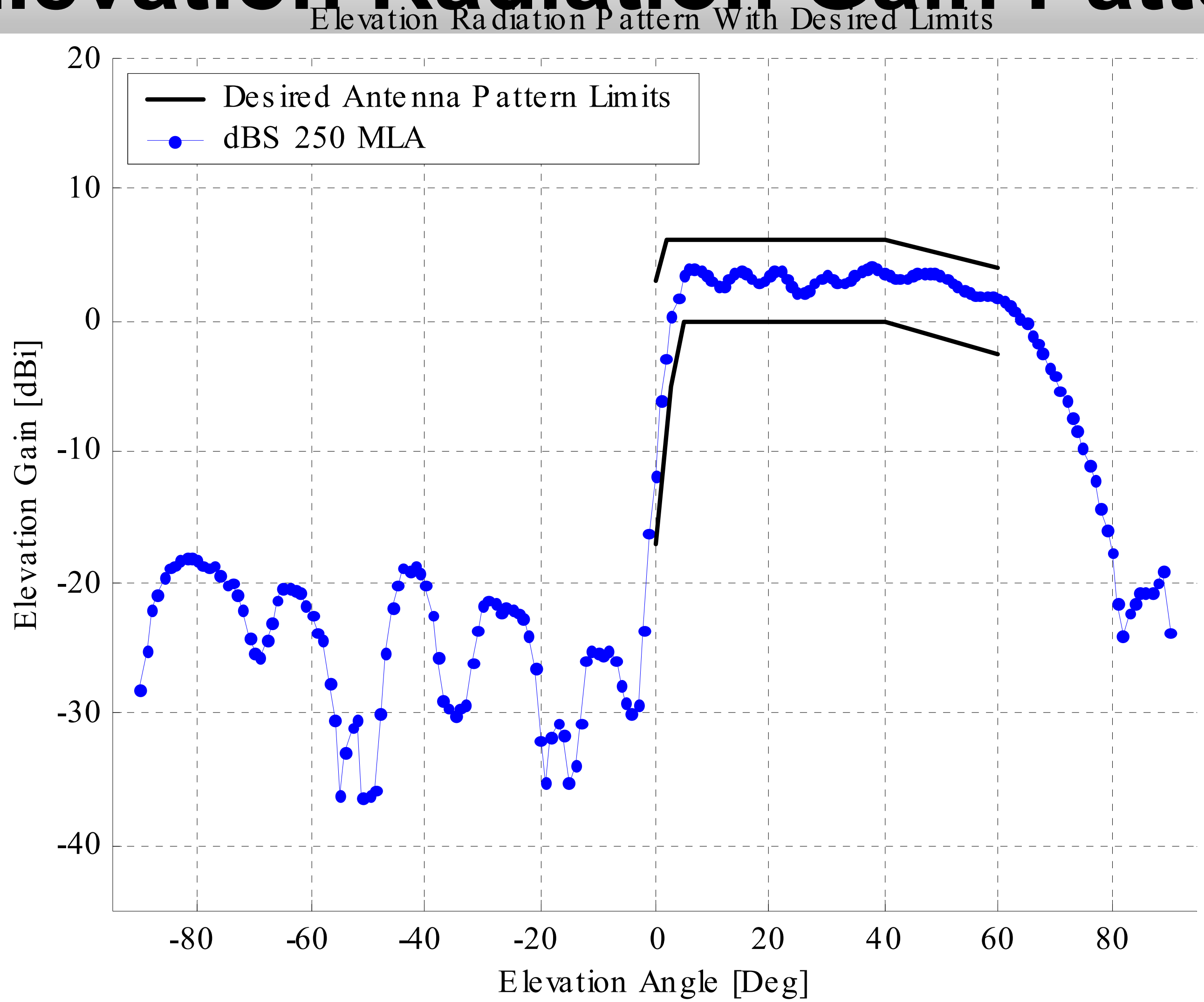
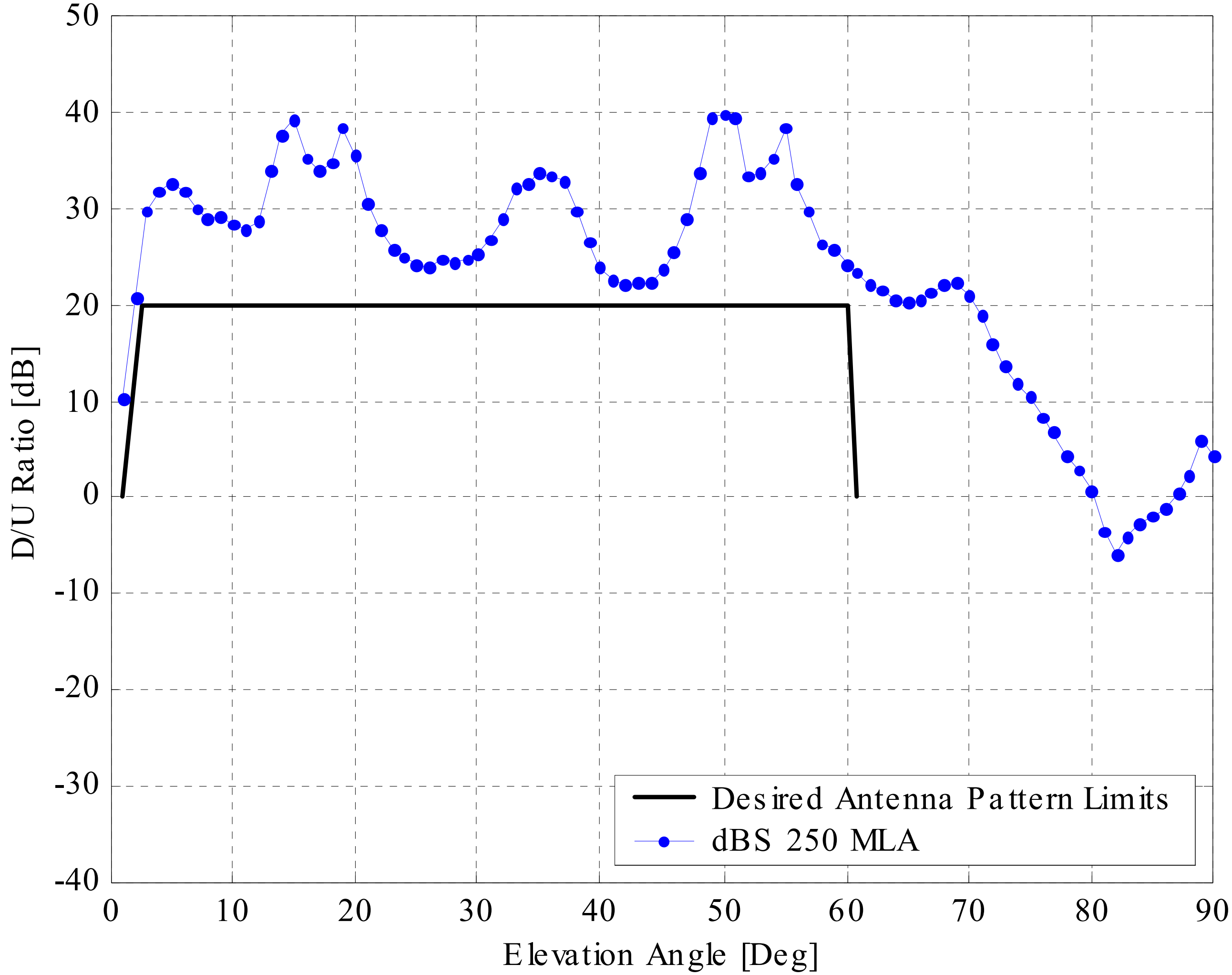
Elevation Radiation Gain Pattern

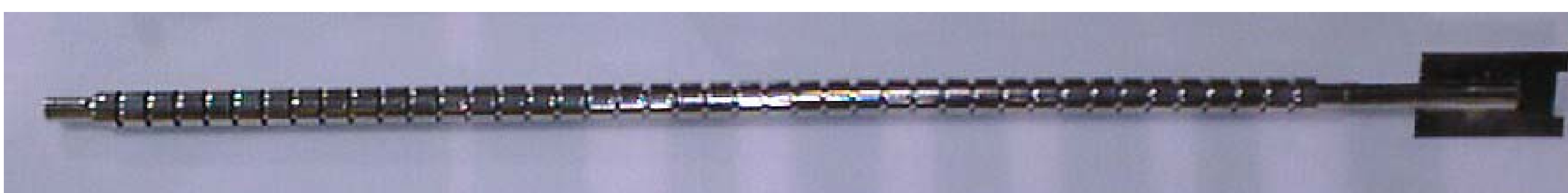


Desired to Undesired Ratio



Physical Description

- **Cylindrical, Co-linear, Dipole Elements Which Provides Vertical Polarization for Ground to Air Link**
  - » **Better Multipath Performance**
  - » **Better Ground to Air Coupling**
- **Pattern Shaping is Achieved by Carefully Controlling the Amplitude and Phase Feed Distribution.**
  - » **Synthesized in Software**
  - » **Optimized for Attainability**



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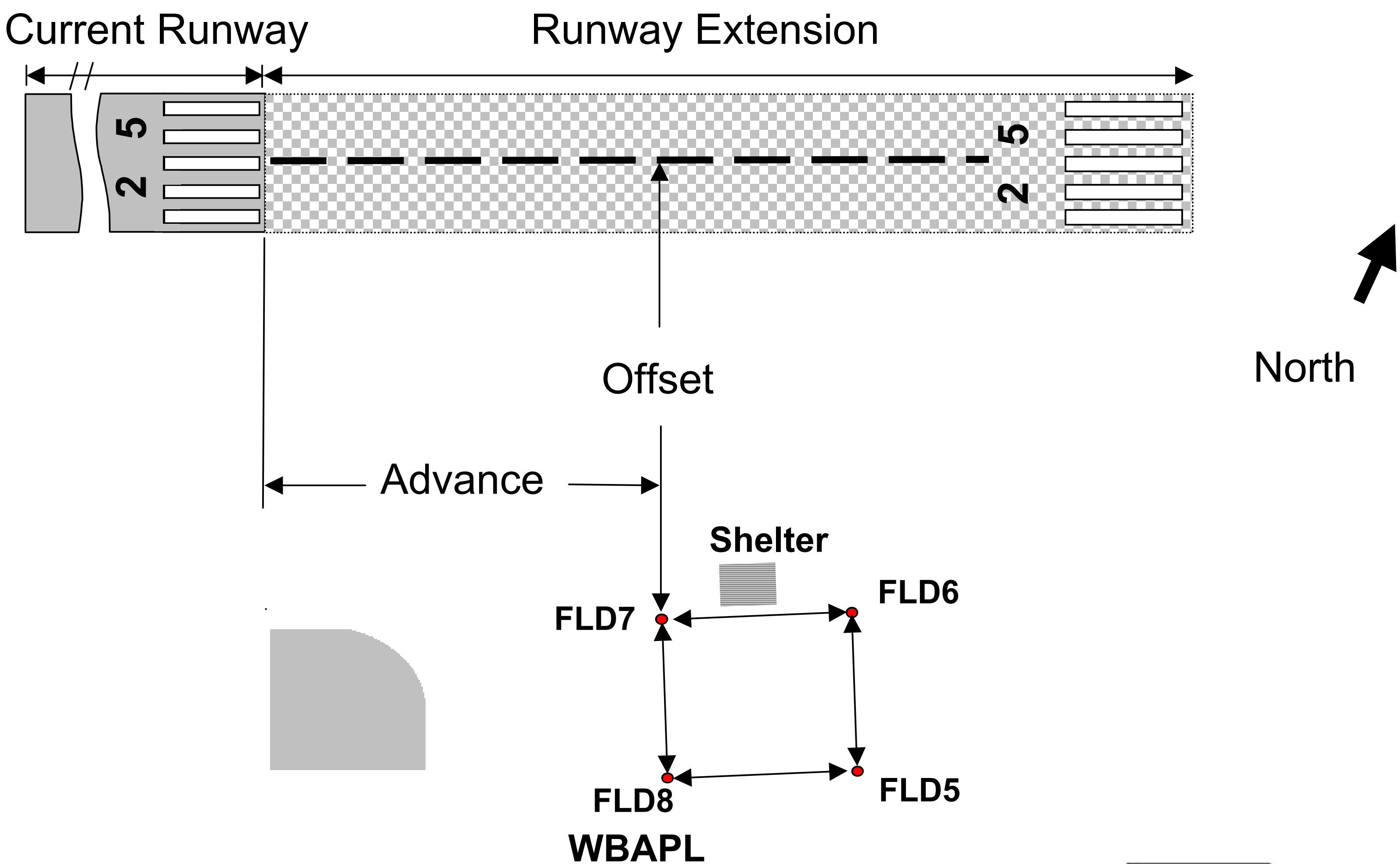
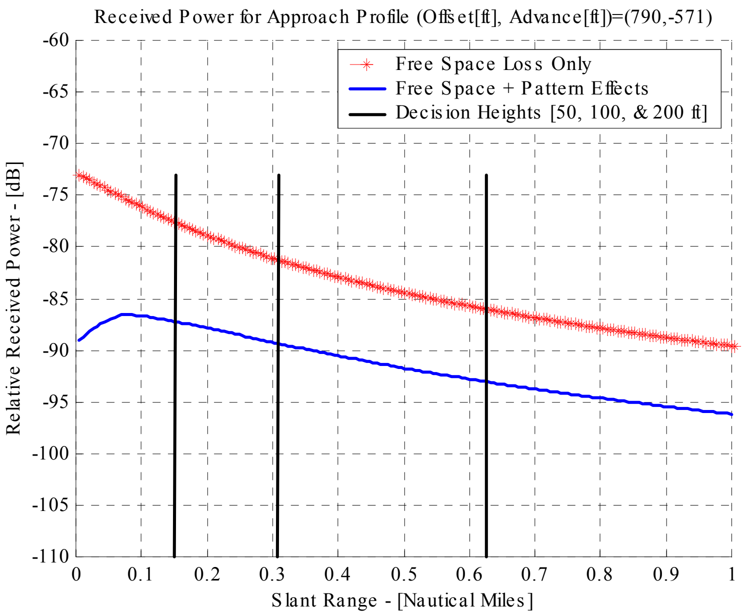


Note: Not Shown to Scale

Theoretical Dynamic Range For the WBAPL Link

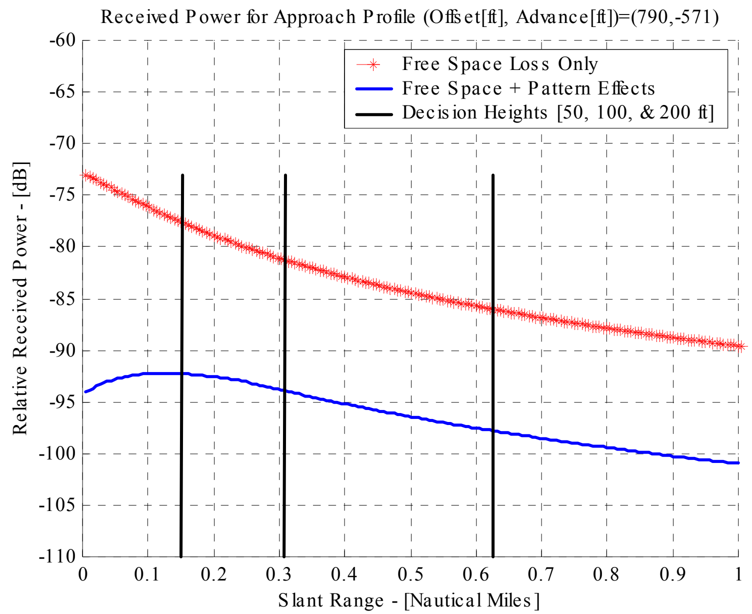
WBAPL MLA



P_R = -125.5 dB @ 35 nmiles

Dynamic Range = -86.5 + 125.5 = 39 dB

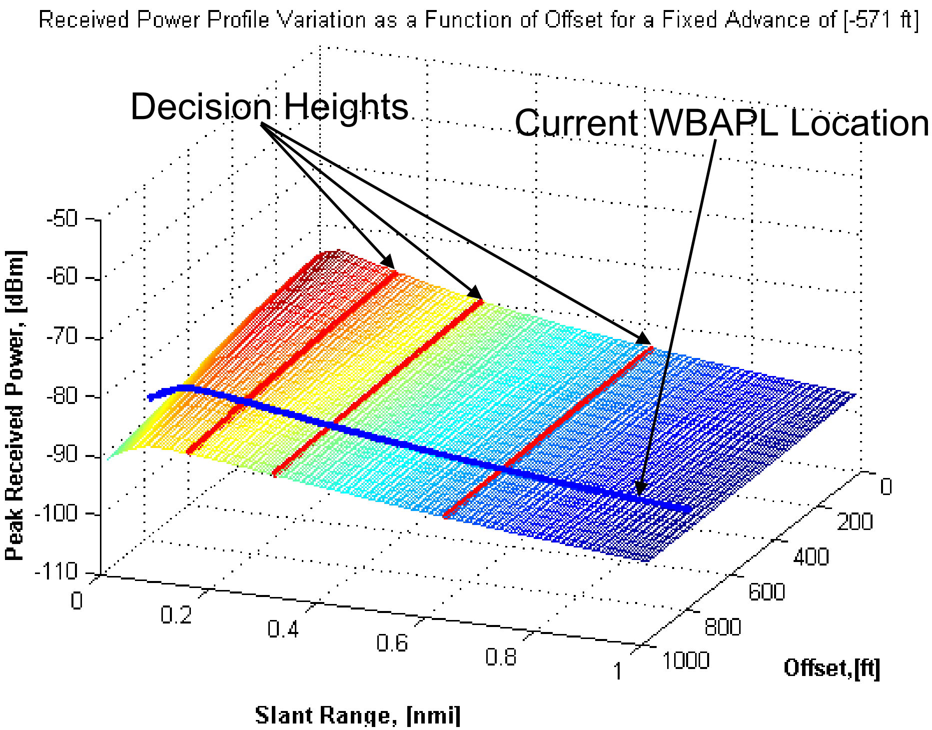
IMLA



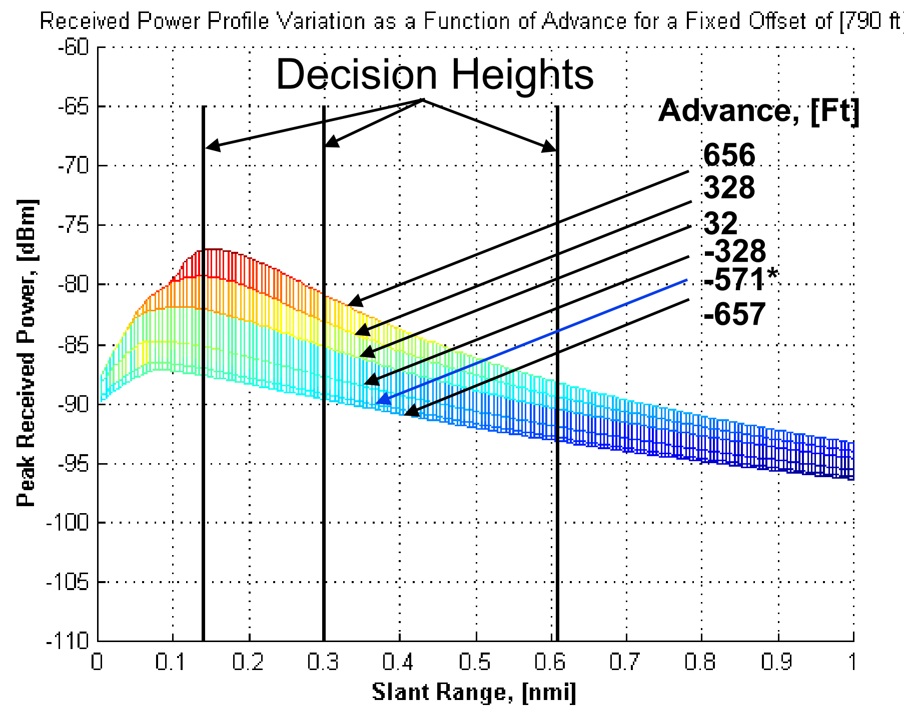
P_R = -130.5 dB @ 35 nmiles

Dynamic Range = -92.25 + 130.5 = 38.25 dB

Power Profile Movement Trends



Variable Offset, Fixed Advance



Variable Advance, Fixed Offset

Code Minus Carrier Analysis

- **Currently Conducting a Code Minus Carrier Analysis to Characterize the WBAPL MLA Multipath Performance.**

$$\rho = r + I + T + c\left(\delta t_u + \delta t^s\right) + \varepsilon_\rho$$

$$\phi = r - I + T + c\left(\delta t_u + \delta t^s\right) + N + \varepsilon_\varphi$$

$$r_{CMC} = \rho - \varphi = 2 \cdot I + N + \varepsilon_\varphi + \varepsilon_\rho$$

Where:

r = True range, user to satellite	[m]
I = Ionospheric propagation delay	[m]
T = Tropospheric propagation delay	[m]
c = WGS84 speed of light in a vacuum	[m/s]
δtu = User clock bias	[s]
δtsv = Satellite clock bias	[s]
N = Carrier Phase Integer Ambiguity	[m]
ε = Other Error Terms	[m]

Multipath Exposure

- **In order to Expose the Multipath, Some Error Terms Must be Removed.**

$$r_{CMC} = \rho - \varphi = 2 \cdot I + N + \varepsilon_{\varphi} + \varepsilon_{\rho}$$

- **The Ionospheric Variation can be Removed by Subtracting a Polynomial Fit.**
- **The Integer Ambiguity is a Constant Bias in the Residual.**
  - » **It can be removed by subtracting the mean as long as there are no carrier phase cycle slips.**

Multipath Isolation - Continued

- **Finally, the Remaining Error Is Filtered to Highlight Multipath Using a Recursive Filter.**

$$CmC_{sm}^{k} = \frac{1}{N} CmC_{raw}^{k} + \frac{N-1}{N} CmC_{sm}^{k-1}$$

Where:

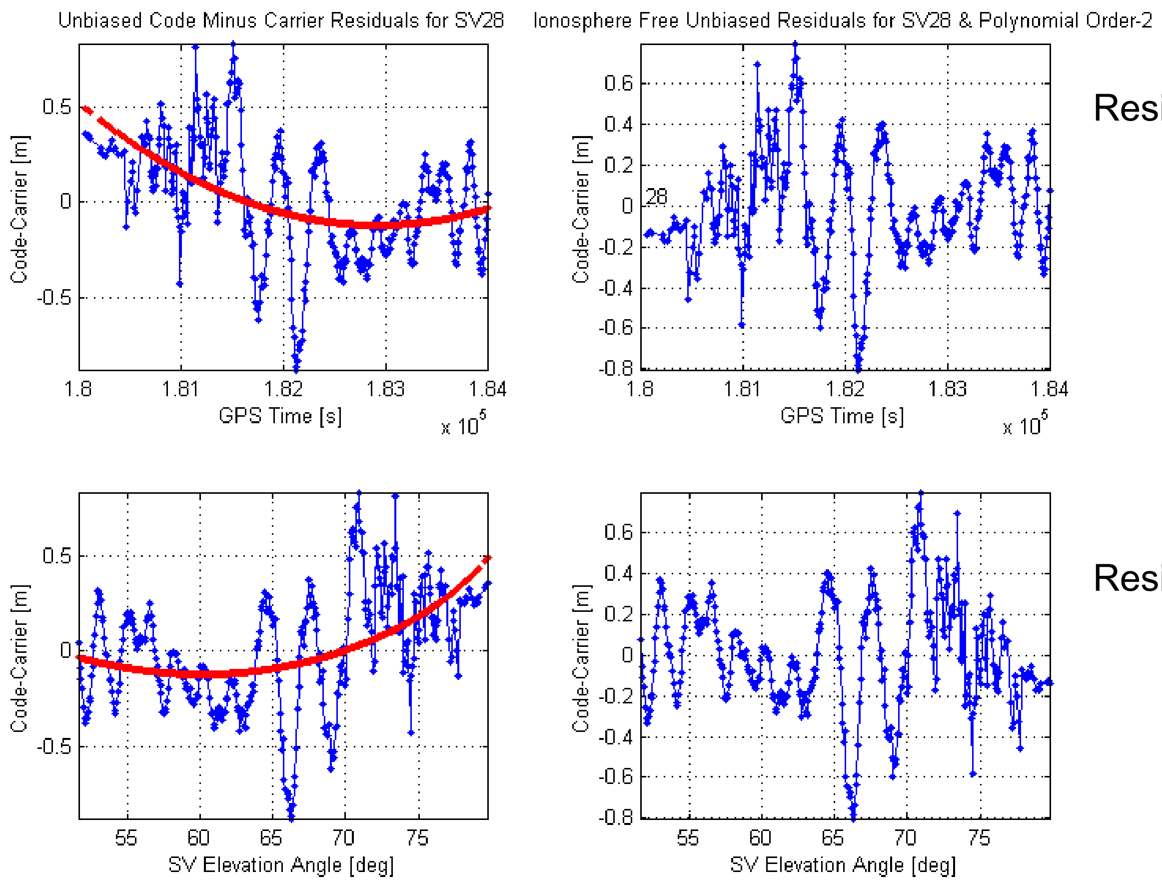
N = Smoothing Constant	[s]
CmC = Code Minus Carrier Residual	[m]
k = Time Index	[unitless]
raw = Raw Measurement	
sm = Smoothed Measurement	

Preliminary Results for SV28

Integer Ambiguity Removed | Polynomial Fit Removed

Residual Versus Time

Residual Versus Elevation



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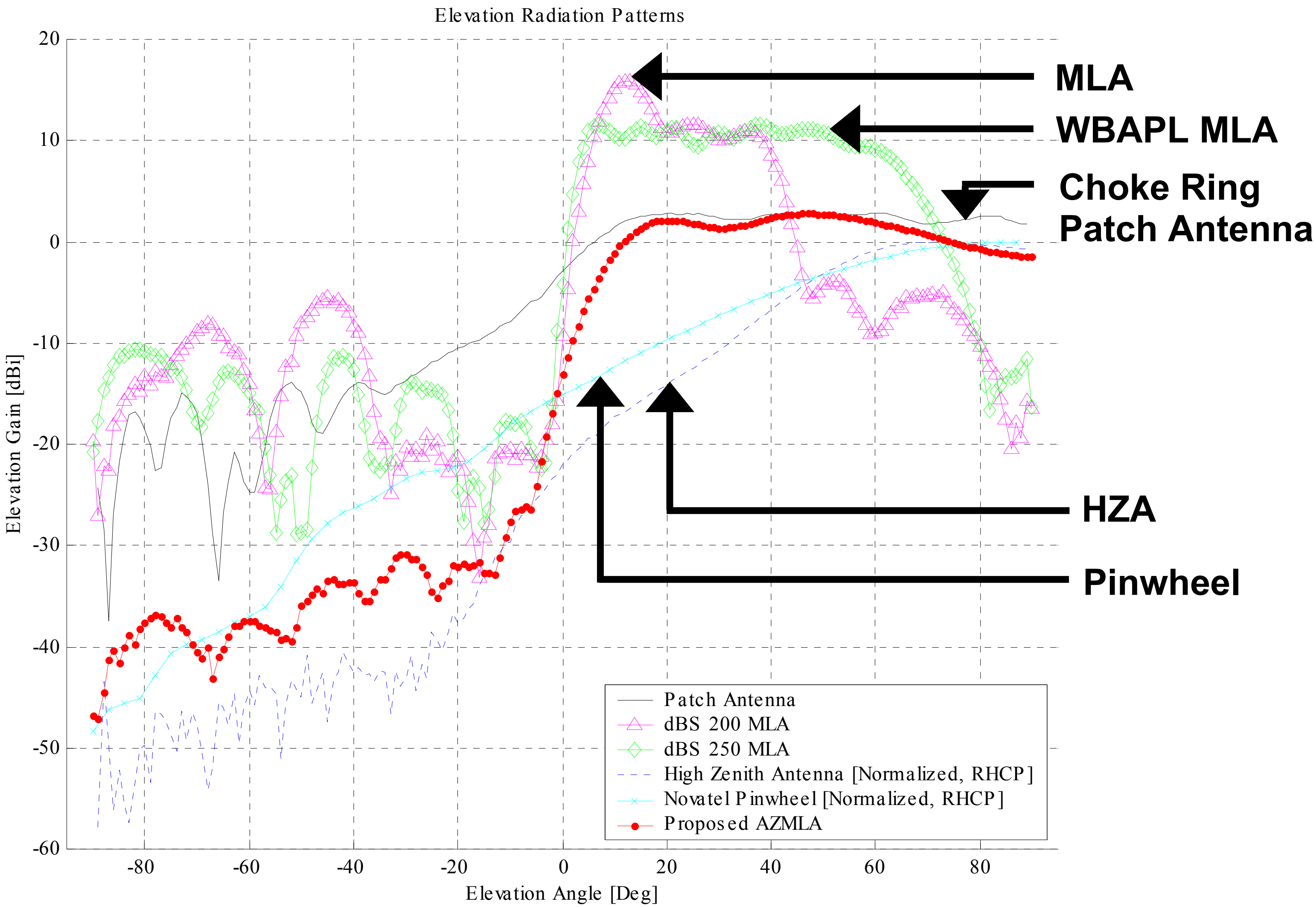
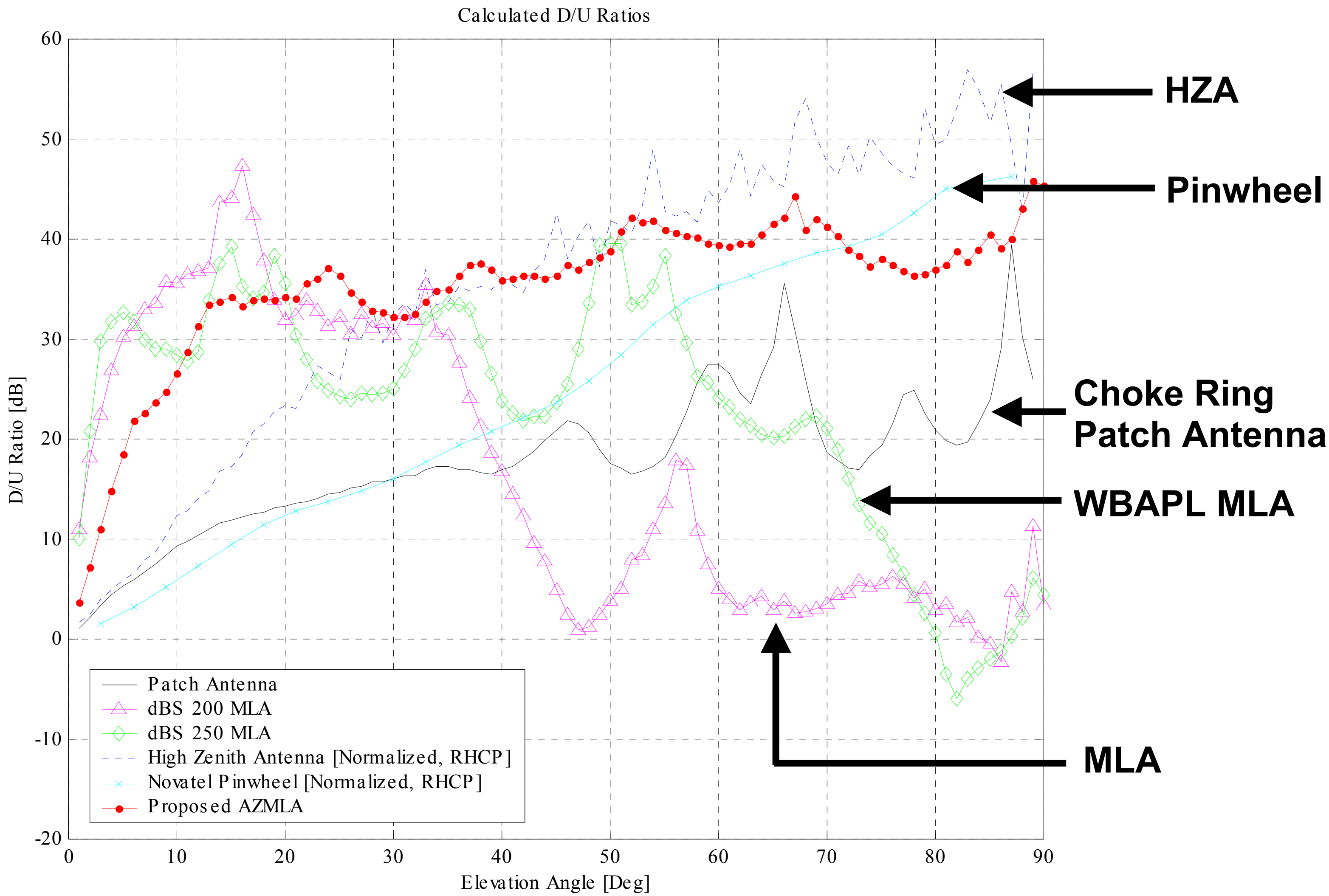
Elevation Gain Pattern Comparison



D/U Ratio Comparison



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Questions?